Measuring and Harnessing Alberta's Wind Resources

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Foreword

Since 1976, numerous projects have been initiated in Alberta by industry and by academic research institutions which are aimed at better utilization of Alberta's energy resources.

These research, development and demonstration efforts were funded by the Alberta/Canada Energy Resources Research Fund (A/CERRF), which was established as a result of the 1974 agreement on oil prices between the federal government and the producing provinces.

Responsibility for applying and administering the fund rests with the A/CERRF Committee, made up of senior Alberta and federal government officials.

A/CERRF program priorities have focused on coal, energy conservation and renewable energy and conventional energy resources. Administration for the program is provided by staff within the Scientific and Engineering Services and Research Division of Alberta Energy.

In order to make research results available to industry and others who can use the information, highlights of studies are reported in a series of technology transfer booklets. For more information about other publications in the series, please refer to page 10.

Measuring and Harnessing Alberta's Wind Resources

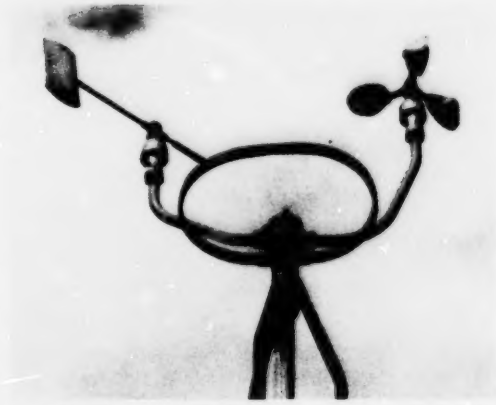
Beginning with the earliest settlers who came to Alberta in the late 1800s, and intermittently since then, Albertans have harnessed the wind and used it for practical purposes. At first, farmers used windmills to pump water for livestock long before electric pumps were available. Even after electricity was commonplace in cities, it was some time before power lines reached into rural areas. By the 1950s, rural communities and farmsteads had become electrified and from then until the 1970s windmill useage declined.

Occasionally a windmill would be purchased to help drain some land or pump water for livestock at a location so remote from power supplies that the cost of installing new power lines was prohibitive. At other times, electricity generating windmills were purchased to operate an assortment of stationary equipment. During the 1970s, Albertans became interested in windmills again because new models, offering greater capabilities, entered the marketplace. As more people approached government agencies and industry for information on windmills, it became apparent that investigations of Alberta's wind resources were warranted. This prompted two studies, one of which began in 1977.

Over the years, meteorological agencies, including the Atmospheric Environment Service (AES) of Environment Canada, have measured wind speed and direction at a number of Alberta locations, and at more than 400 monitoring stations across Canada. Analysis of this information showed that wind speed and direction can be influenced by local topography and nearby obstructions that redirect the wind Also, wind characteristics can change with elevation above ground. Consequently, measurements taken at one location are not necessarily indicative of wind behaviour at another, nearby location. In Alberta's case, wind monitoring stations were so far apart it was felt that measurements should be made at additional locations if a reasonable assessment of the province's wind resource was to be made.

Solar and Wind Energy Research Program (SWERP)

Because wind resource information was required at additional locations in Alberta, wind speed and direction were measured at seven locations from 1977 to 1985 as one component of the Solar and Wind Energy Research Program



Typical SWERP monitoring stations included instruments to measure wind direction and speed.

(SWERP) funded by A/CERRF and under the direction of Alberta Research Council. (Results of the solar monitoring portion of the program were published in "Solar Energy Potential for Alberta", ENR No. I/145, available from Alberta Energy Information Centre. See page 10.)

Wind data were recorded at the following sites: Fort McMurray, Edson, Ellerslie, Rocky Mountain House, Coronation, Pincher Creek and Lethbridge At each location the same types of cup anemometers and wind direction sensors employed at AES stations were used.

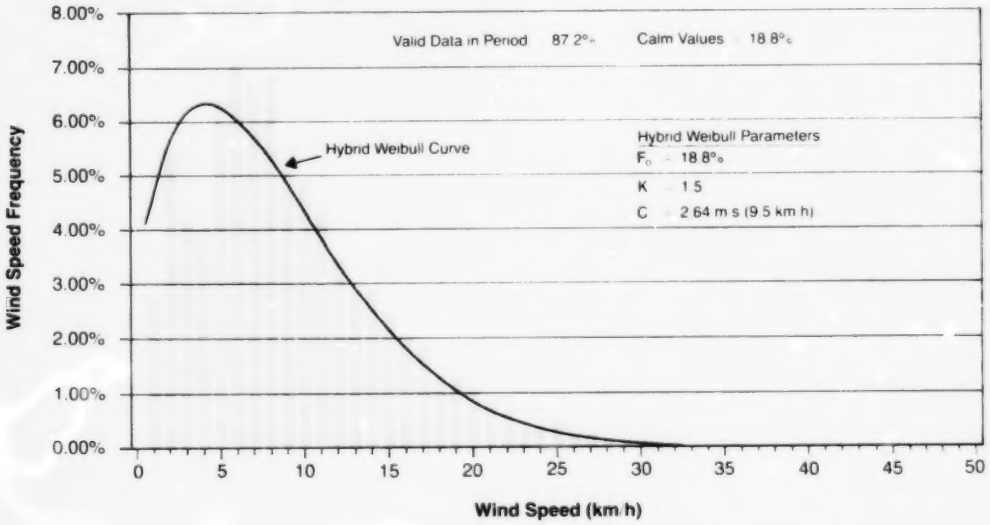
Monthly and annual averages of wind speed and direction at each station were tabulated. Before the information could be used to calculate potential energy yields, either in the form of generated electricity or volume of pumped water, which might be produced by wind conversion devices such as windmills, it was necessary to calculate the statistical distribution of wind speeds. From this, the likelihood of encountering a particular wind speed, at any time, and at each monitoring station could be determined.

This was done by using a mathematical equation called a Hybrid Weibull Distribution to produce a graphical representation from which the frequency of occurrence of wind speeds within any specified range could be calculated. For example, a comparison of the wind distribution curves for Fort McMurray and Lethbridge reveals that higher wind speeds occur more often in Lethbridge than in Fort McMurray but low wind speeds of about 5km/h occur more than twice as often in Fort McMurray than in Lethbridge.

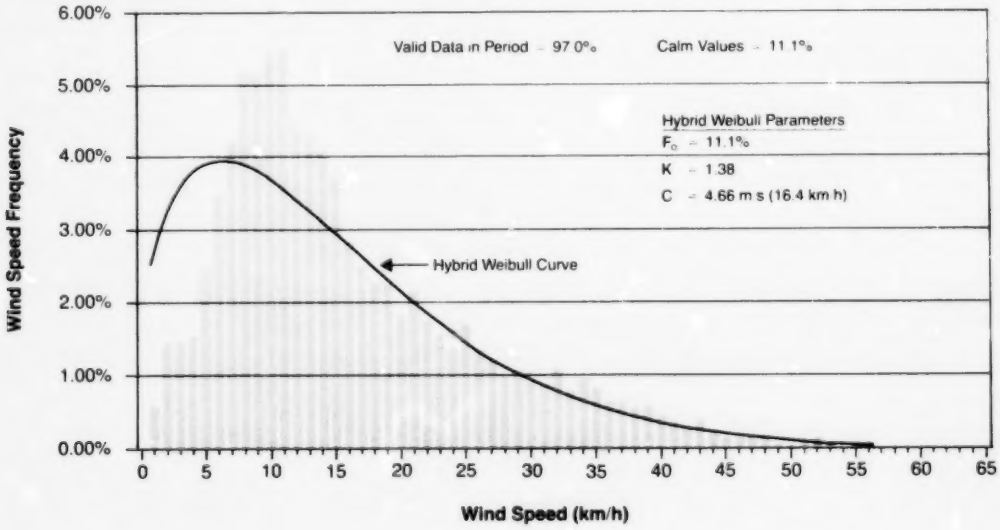
From data like this it is possible to predict the annual volume of water that could be pumped by a water-pumping windmill located at Pincher Creek or wherever reliable wind data had been collected.

Because wind measurements were taken over a much shorter time period than is the case at AES stations, it can be argued that, statistically, the SWERP data are less reliable but, at the same time, it is clear that the SWERP study provided valuable information about Alberta's wind resources, sufficiently so that by 1985 it was felt the program had achieved its objectives, at which time it was phased out. Furthermore, the expertise gained by Alberta Research Council led to further, related investigations on behalf of other clients.

Fort McMurray Wind Speed Frequency Period April 1984 to March 1985



Lethbridge Wind Speed Frequency Period January 1983 to December 1983



(Source: *Solar and Wind Energy Monitoring Project 1977-85*, Alberta Research Council, 1986)

Water-Pumping Wind Turbines

Meanwhile, farmers and ranchers had been asking questions about the new windmills that were on the market. They wanted to know more about their performance, reliability and cost-effectiveness. Because the answers were not readily available, it was decided that one way to obtain this information would be to test several windmill designs over a period of time in southern Alberta, which tends to be windier than other regions of the province.

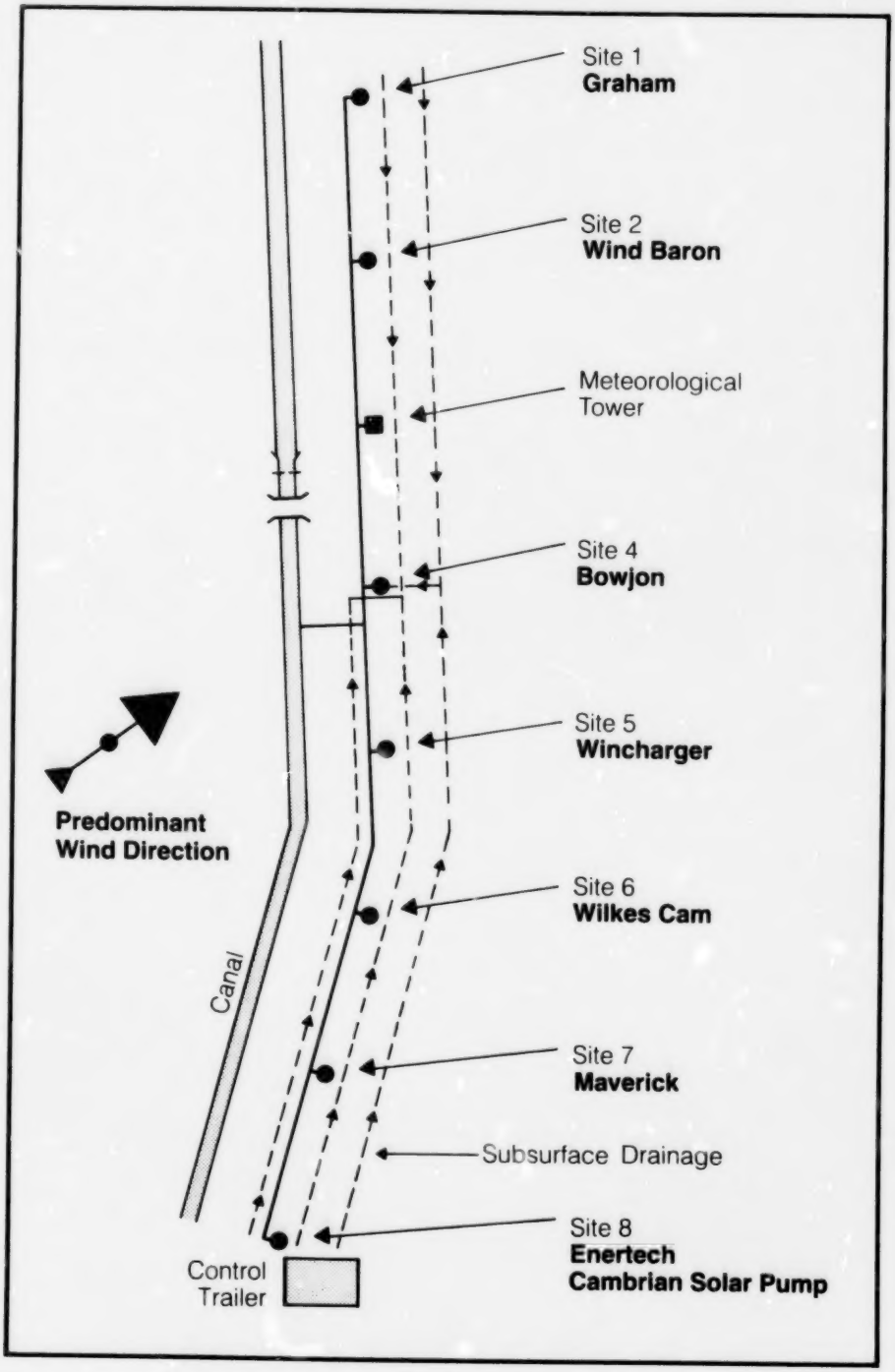
Beginning in 1983, at a test site established beside a St. Mary River Irrigation District canal at Lethbridge, the water-pumping characteristics of six wind turbines were measured in a closed loop configuration which allowed each turbine to pump water at measured flow rates and then recirculate it to its source. Concurrently, wind velocity and direction were monitored so that the volume of pumped water could be related to wind speed. Also, a solar-powered pump and a small electricity generating turbine were tested. The investigation, which continued for three years and was of interest to both the agricultural community and wind turbine manufacturers, was funded by A/CERRF as well as Farming for the Future and the Drainage Branch, both of Alberta Agriculture, and TransAlta Utilities Corporation.

Because wind characteristics are a function of local conditions, such as terrain, detailed measurement of atmospheric conditions was necessary. Included were wind speed measurements at heights of seven to sixteen metres above ground, wind direction at ten and sixteen metres elevation, ambient temperature and pressure and vertical wind speed.

The six water-pumping wind turbines represented a reasonable cross-section of machines available on the market. They included the following mechanical water pumpers: the drum-like, single rotor Graham 12, which is designed on the Savonius principle, and two multi-blade units, the Wilkes Cam and Wind Baron with rotor diameters of 3.7 metres and 6.4 metres respectively. Two airlift turbines (a Bowjon and a Maverick) used compressed air to lift water. A Wincharger unit was tested also. Its rotational action generated DC power which was used to operate a small, centrifugal pump. An electricity generating windmill, the Enertech 1800, was tested to compare actual versus rated power output. Finally, a portable solar-pumping unit comprising six photovoltaic panels, with a rated output of 500 W, was tested by connecting it to a variable voltage submersible pump.

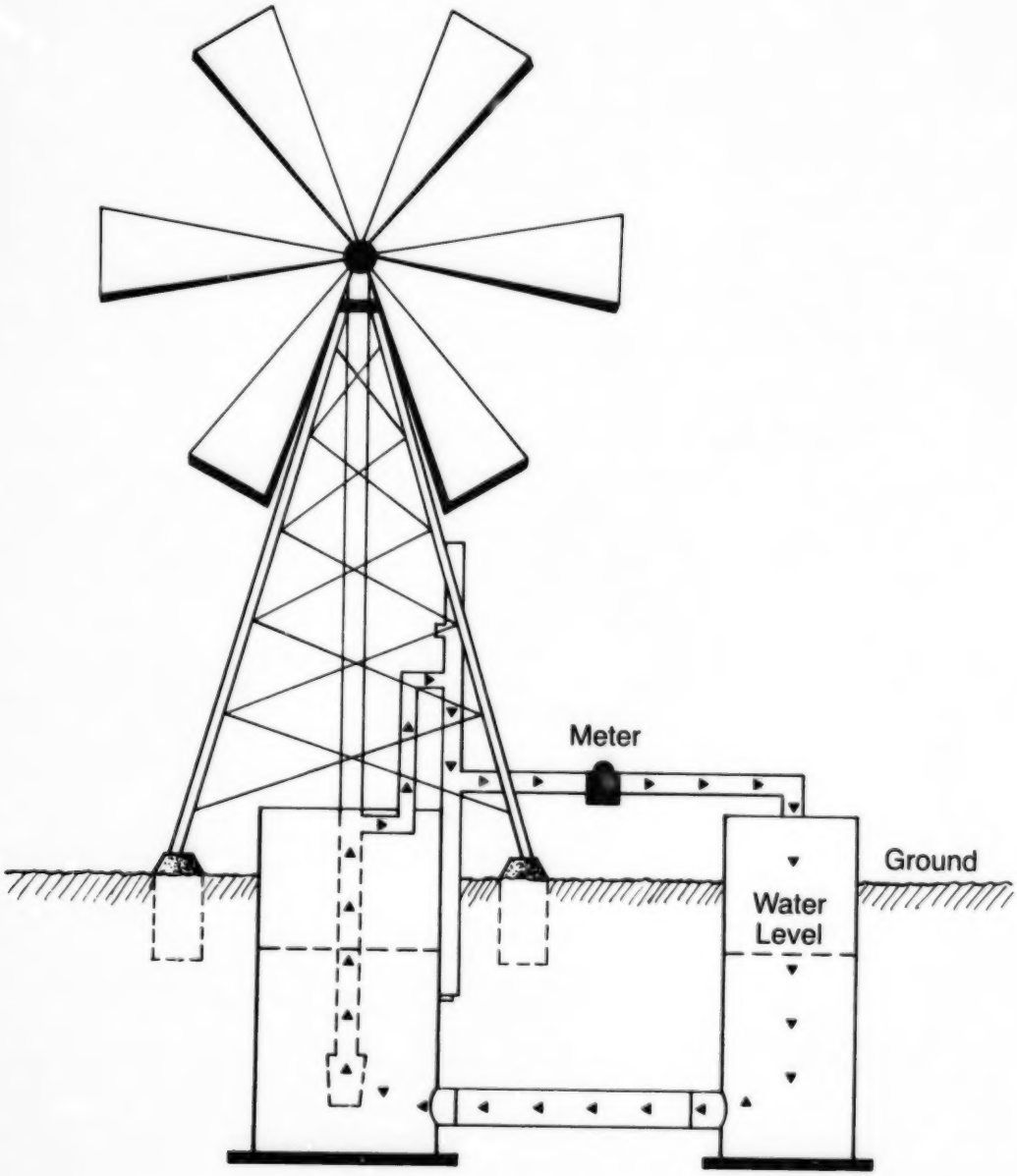
Wind measurement instruments and some of the wind machines tested at Lethbridge.

Windmill Test Site



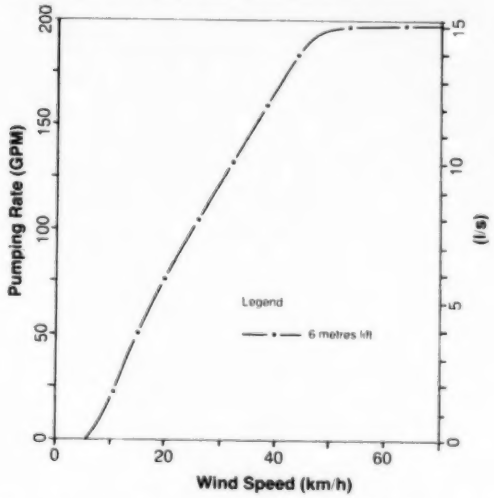
(Source: *Evaluation of Low Wind Turbines for Pumping Water*, Alberta Agriculture, 1985)

Pumping Circuit

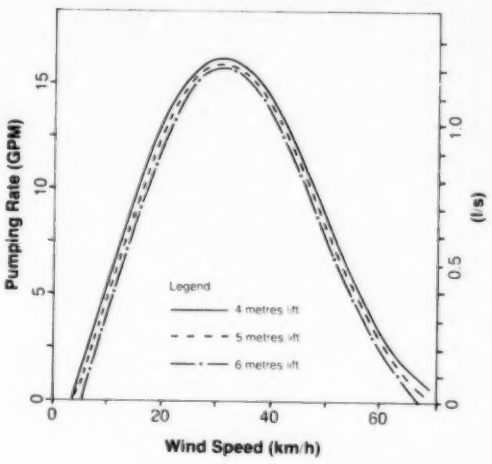


(Source: *Evaluation of Low Wind Turbines for Pumping Water.* Alberta Agriculture, 1985)

Wind Baron Pumping Performance



Wilkes Cam Pumping Performance



(Source: *Evaluation of Low Wind Turbines for Pumping Water*. Alberta Agriculture. 1985)

For each machine, pumping flow rates, turbine rotor speed and rotor power output at varying pumping heads were measured. Also, peak wind gusts were measured in case any of the turbines failed because of high winds.

These measurements were related to known wind regimes at various monitoring stations in Alberta to provide an indication of the performance that might be expected from them if they were used at those locations. In this way a prospective windmill user could determine whether a wind turbine would be a cost-effective device for a particular water-pumping task at Grande Prairie, for instance, or conclude that a pump operated by electricity, diesel fuel or natural gas might be preferable.

The study, under the direction of the Drainage Branch of Alberta Agriculture and carried out in co-operation with Jensen Engineering of Olds and Alberta Research Council, continued throughout most of the 1983 irrigation season and from mid-May to mid-October 1984.

Signals generated by the various sensing devices were directed to an ICIS 850 data acquisition system which produced information for analysis at the test site, but also allowed data to be transmitted to the University of Alberta mainframe computer in Edmonton from which performance curves for each machine were prepared according to widely accepted standards established by the International Energy Agency.

Once the performance curves were produced, each turbine's pumping potential was calculated using Hybrid Weibull Distributions of wind speeds. This indicated the suitability of each turbine for particular water-pumping applications.

Perhaps the most important outcome of the investigation was the observation that machines which pump at lower wind speeds have substantially more pumping potential under Alberta conditions than those which are designed to capture higher wind speeds. For example, a unit that began to pump when the wind speed was only 5 km/h could pump 50 per cent more water per year than a unit which did not begin to pump until the wind speed had reached 21 km/h. Also, the Enertech machine, which did not cut in until about 19 km/h, probably would not be as suitable in areas like Edmonton and Grande Prairie, which have low average wind speeds, as in southern Alberta where average wind speeds are higher.

With the exception of the Wind Baron, none of the turbines suffered any major breakdowns during the two or three year test period. The Wind Baron suffered frequent problems with the rotor assembly and on one occasion the assembly sheared off. This prompted the manufacturer to redesign the machine. Furthermore, turbine manufacturers who wish to sell products in Alberta now realize that their machines should be designed to capture the low end of the wind regime instead of maximizing output at higher wind speeds.

Cost analyses were prepared for each unit which compared capital and long-term operating costs with the alternatives of using electrical, diesel or natural gas pumpers at particular locations.

In the report, "Evaluation of Low Volume Wind Turbines for Pumping Water", sample calculations are provided to illustrate the use of test data in evaluating the suitability of each machine for typical field applications.

Cost analyses showed that subsidies in the form of grants and low interest loans give electric systems an advantage in certain situations because similar assistance is not available for windpump installations. Nevertheless, the windpump alternative is attractive if the machine is a proven unit and has a 20 to 25 year life expectancy. Also, its installed cost should be less than an electric system and its annual operating costs should not exceed 2.5 per cent of the total capital costs. Units selling for $5,000 to $10,000 are expected to be popular in Alberta.

For the solar water pumper, it was not possible to calculate monthly pumping volumes because the required solar radiation data for Lethbridge were not available. Performance measurements suggested that a tracking collector system, as opposed to fixed, tilted panels used in the experiment, might allow water pumping for longer periods of time on clear days and on typical days when clouds build up in the afternoon.

The test program generated considerable public interest. During two demonstration days when the site was open to the public, crowds of 200 to 300 toured the facility. At other times, tours were arranged for visitors from Europe, the U.S. and other parts of Canada. Also, numerous manufacturers expressed interest in having their machines tested at the site. Consequently, the test program was extended for an additional three year period.

During the first year of the extended test period, two wind turbines were tested under winter conditions typical of southern Alberta.

This was the first time that winter testing was attempted. It was regarded as an important aspect of the program because in certain drainage applications there is a need to continue operations until freeze-up. Also, on hydroelectric projects, where wind turbines might be used to pump water into reservoirs, it is expected that year round operation would be necessary.

Two turbines, a Chinook multi-bladed unit manufactured in Calgary and employing a design by the Intermediate Technology Institute of England, and a Deltx WP-20 delta blade machine manufactured by Abax Energy Services Ltd. of Calgary, were prepared for winter testing.

Because the Chinook unit experienced mechanical problems with the rotor assembly and the pump apparatus, performance data could not be obtained. In the case of the Deltx machine, even though long delays caused by inclement weather were experienced whenever mechanical difficulties arose, enough data were obtained to make some observations.

Preliminary results showed that the WP-20 outperformed all other wind turbines previously tested in terms of annual volume of pumped water, maximum pumping volume and annual volume pumped per square foot of swept area. Because cold temperatures made it difficult to perform any type of repair work on either machine, it was decided that winter studies would not be attempted in the future.

More information about Alberta's wind energy resources can be obtained by contacting the following:

1. For access to SWERP monitoring data contained in the publication *Solar and Wind Energy Monitoring Project 1977-1985*, contact:

   Industrial and Engineering Research Division
   Alberta Research Council
   250 Karl Clark Road
   Edmonton, Alberta
   T6N 1E4

   Telephone: (403) 450-5451

   or in Calgary at:

   3rd Floor, Digital Building
   6815 - 8th Street, N.E.
   Calgary, Alberta
   T2P 7H7

   Telephone: (403) 297-2600

2. Performance data pertaining to specific water pumping wind turbines may be obtained from:

   B.A. Paterson
   Head, Drainage Branch
   Irrigation and Conservation Division
   Alberta Agriculture
   Agriculture Center
   Lethbridge, Alberta
   T1J 4C7

   Telephone: (403) 381-5515

Additional copies of this publication are available from:

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